



First report of the Southern Gulf Coast Toad (*Incilius valliceps* Wiegmann), Common House Gecko (*Hemidactylus frenatus* Duméril and Bibron), Schmidt's Black-Striped Snake (*Coniophanes schmidtii* Bailey), and Cozumel Whiptail (*Aspidoscelis cozumela* Gadow), on Turneffe Atoll, Belize

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Abstract

Each year from 2012 to 2019, during a 12-day period in November or December, we photographed common herpetofauna on Calabash Caye, a small mangrove-dominated island on the eastern edge of Turneffe Atoll, Belize. Turneffe Atoll is home to the newest, largest, and most biodiverse marine protected area in Belize. Calabash Caye exemplifies the islands on Turneffe's eastern edge whose elevated beach ridges enable the development of coastal strand plain and littoral forest habitats, which are among the most threatened habitats in the world. As no herpetofaunal survey has been published for Turneffe in over twenty years, and as the herpetofauna is a conspicuous indicator of the health of terrestrial ecological communities on islands, we leveraged our annual field excursions to Calabash Caye to compile a photographic record of the island's reptiles and amphibians. In multiple years, we documented the presence of five lizards (*Anolis sagrei mayensis*, *Aspidoscelis cozumela*, *Ctenosaura similis*, *Phyllodactylus tuberculatus*, and the invasive species *Hemidactylus frenatus*), three snakes (*Boa imperator*, *Leptophis mexicanus hoeversi*, and *Coniophanes schmidtii*), and one amphibian (*Incilius valliceps*). This represents the first report of *A. cozumela*, *H. frenatus*, *C. schmidtii*, and *I. valliceps* on Calabash Caye or on any island in Turneffe Atoll; *H. frenatus*, *C. schmidtii*, and *I. valliceps* have never been reported on any of the Belizean cayes. We did not observe four species that have previously been reported on Calabash Caye: Brown Basilisk (*Basiliscus vittatus*), Mesoamerican Cane Toad (*Rhinella horribilis*), Mayan Skink (*Marisora lineola*; formerly *Mabuya unimarginata*), or a blindsnake, provisionally identified as *Indotyphlops braminus*. We also include photos of *Anolis allisoni*, *Ctenosaura similis*, and *Anolis sagrei mayensis* obtained during four single-day excursions to Half Moon Caye on Lighthouse Atoll; this represents three of four species reported from that location during the 1990s.

Keywords: Amphibian, Calabash Caye, Caribbean, conservation, distribution, introduced species, invasive species, reptile.

Introduction

Turneffe Atoll, located ~33 km off the coast of Belize, represents the western extent of the "Caribbean Islands" geographic region (Hedges *et al.*, 2019). It is also the largest oceanic atoll in the Western Hemisphere (Stoddart, 1962) and the site of Belize's newest, largest, and most biodiverse marine reserve (Turneffe Atoll Sustainability Association, 2020). While the principal management aim of the reserve is to conserve the fragile marine environments, approximately 20% of the area encompassed by Turneffe Atoll consists of terrestrial habitats, divided among hundreds of cayes, ranging in size from small sandbars to an 11,000-acre landmass (Turneffe Atoll Sustainability Association, 2020). The beaches, littoral forests, and mangrove forests found on these islands support a diverse and biologically important assemblage of terrestrial organisms (Meerman, 2006).

Obtaining accurate species inventories is critical to the conservation and management of Turneffe, particularly to establish a baseline against which we can evaluate the ecological effects of environmental change, management decisions, or changes in the utilization of the atoll. Amphibians and reptiles are the two major vertebrate groups of endemic species on Caribbean islands (Hedges *et al.*, 2019), and the herpetofauna is a particularly conspicuous component of the terrestrial fauna on many Belizean cayes, including those that comprise Turneffe Atoll. Reptiles, and to a lesser extent, amphibians can be highly abundant, and have a proportionately large impact on the ecology of these semi-isolated terrestrial ecosystems. Unfortunately, very few data address the abundance and diversity of terrestrial reptiles and amphibians on Turneffe Atoll, a concern that has existed for decades; indeed, no report on the overall herpetofauna of Turneffe Atoll has been published in the last twenty years, a period of accelerating environmental change and species loss (Platt *et al.*, 1999).

To update the herpetofaunal inventory on Calabash Caye, a small mangrove-dominated island on the eastern edge of Turneffe Atoll, we compiled photographs of five species of lizards, three species of snakes, and one species of toad. All the photos were taken during one of eight 12-day field trips, undertaken in November or December of 2012 through 2019. The photographic sampling we conducted was opportunistic, documenting those species that could be observed from developed areas of the island as well as the edges of strand plain habitat and littoral forest bordering these areas. The sampling was therefore biased toward species that are relatively common, accessible, and conspicuous. Despite these sampling limitations, we obtained the first records of the Common House Gecko (*Hemidactylus frenatus*), Cozumel Whiptail (*Aspidoscelis cozumela*), Schmidt's Black-Striped Snake (*Coniophanes schmidtii*), and Southern Gulf-Coast Toad (*Incilius valli-ceps*) on Turneffe Atoll. We also include photos of three lizards observed during four day-long excursions to Half Moon Caye on Lighthouse Atoll. All photos are accessible through the media library of the Boston University Marine Program (bumarine.smugmug.com/ORGANISMS/METAZOA-animals/CHORDATA).

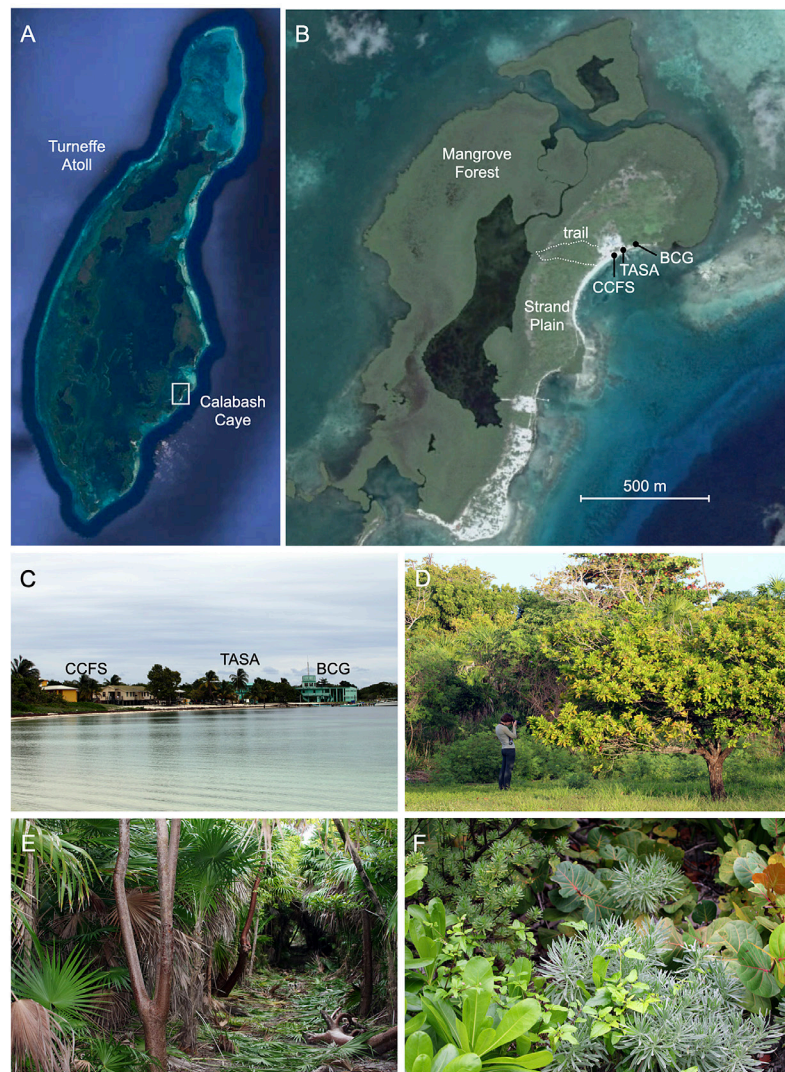


Figure 1. Study Site. Satellite views of (A) Turneffe Atoll and (B) Calabash Caye. Abbreviations are: BCG = Belize Coast Guard; CCFS = Calabash Caye Field Station; TASA = Turneffe Atoll Sustainability Association. The structures built to house the Belizean Coast Guard's operating base, erected in 2010, and the Turneffe Atoll Sustainability Association's operating base, erected in 2015, are not depicted in the satellite image. (C) View of the eastern shore of Calabash Caye. (D) Manicured habitat adjacent to the trail head, west of the field station. (E) View of the trail depicting representative vegetation. (F) Representative vegetation in the strand plain habitat adjacent to the beach. Photo credits: (A, B) The image is dated August 26, 2005 and was obtained using Google Earth Pro (v. 7.3.2.5776). Images © 2020 Maxar Technologies. (C, D) Photos by John R. Finnerty.

Results and Discussion

Site Characterization. Calabash is a small mangrove island located on the eastern rim of Turneffe Atoll (Fig. 1). The sandy, eastern shore of the island is home to the Calabash Caye Field Station (CCFS), operated by the University of Belize, an office of the Turneffe Atoll Sustainability Association, and a forward operating base for the Belizean Coast Guard, as well as four private homes that are only sporadically occupied. The uninhabited portions of Calabash Caye can be divided into two major terrestrial habitats. A strand-plain habitat occupies much of the eastern third of the island, where littoral forest grows on a mixture of sand and coral rubble. Common tree species here include *Bursera simaruba* L., *Cordia sebestena* L., *Coccoloba uvifera* L., *Conocarpus erectus* L., *Metopium brownei* L., *Ponteria campechiana* (Kunth) Baehni, and *Thrinax radiata* Loddiges (Stoddart, 1962; Fosberg *et al.*, 1982). The western two-thirds and northern tip of the island consist of submerged peat covered by mangrove forest, primarily



Figure 2. Lizards previously reported from Calabash Caye. Common Spiny-tailed Iguana, *Ctenosaura similis*: (A) juvenile (November 2015), (B) adult male feeding on vegetation (December 2012), (C) adult female (November 2014), and (D) tail of adult male clinging to a tree trunk (December 2018). Mayan Coastal Anole, *Anolis sagrei mayensis*: (E) resting on discarded lumber (December 2018), (F) clinging to a tree trunk (December 2018). Tuberculate Leaf-toed Gecko, *Phyllodactylus tuberculatus*: (G) individual clinging to the interior wall of a building, with a partially missing right hindlimb (November 2013). Red dots in the enlargement mark individual tubercles between axilla and groin. Abbreviations: DC = dorsal crest; DL = dewlap; IS = intercalary scales; MK = median keel. Photos by John R. Finnerty (A–F) and Lara R. Hakam (G).

Figure 3. Snakes previously reported from Calabash Caye. Central American Boa, *Boa imperator*: (A) Individual photographed on the morning of 12 November 2016 in littoral forest adjacent to the walking trail, (B) enlarged view of the head of the individual shown in (A), (C) individual ingesting a grackle (September 2013), (D) lateral head views of snakes photographed in December 2017 (top) and December of 2018 (bottom). Black arrows indicate an identical pattern of darkly pigmented spots in what appears to be the same individual photographed in consecutive years. DS = dorsal “saddle” marking. Mexican Parrot Snake, *Leptophis mexicanus hoeveri*: (E) an individual observed in shrubs fringing manicured grounds edging the littoral forest (November 2013), (F) a close-up of dorsal scales in the snake shown in (E), (G) a close-up of the head reveals the presence of the loreal scale (LO; November 2013), (H) an axanthic color morph found in the littoral forest fringing the walking trail exhibits a prominent ocular stripe (OS; December 2018). Photos by John R. Finnerty (A, B, D, E–H) and Justin Hall (C).

Rhizophora mangle L. and *Avicennia germinans* L. The mangroves surround an interior lagoon that extends ~500 m from north to south.

Species Accounts. Below, we list the species that we observed, and for those species that have not previously been documented from Calabash Caye, or any of the islands of Turneffe Atoll, we provide photographic documentation of traits used in species identification and the range of intraspecific variability we observed. Taxonomy follows The Reptile Database (Uetz *et al.*, 2020), and common names follow Hedges *et al.* (2019). Only terrestrial herpetofauna are described here. However, we regularly observed American Crocodiles (*Crocodylus acutus* Cuvier 1807) in the surrounding waters and occasionally on the beach, and we have observed sea turtle nestlings on the beach, but did not approach them or attempt to identify them to species.

From 2012 to 2019, we photographed five lizards, three snakes, and one amphibian on Calabash Caye. Three of the lizards (Fig. 2) and two of the snakes (Fig. 3) were described previously as common on Calabash Caye or other islands of Turneffe Atoll (Henderson, 1976a; Zisman, 1992; Lee, 1996; Platt *et al.*, 1999). These are the Common Spiny-Tailed Iguana (*Ctenosaura similis* Gray; Fig. 2A–D), Mayan Coastal Anole (*Anolis sagrei mayensis* Smith and Burger; Fig. 2E–F), Tuberculate Leaf-Toed Gecko (*Phyllodactylus tuberculatus* Wiegmann; Fig. 2G), Central American Boa Constrictor (*Boa imperator* Daudin; Fig. 3A–D), and a subspecies of the Mexican Parrot Snake endemic to Turneffe Atoll (*Leptophis mexicanus hoeversi* Henderson; Fig. 3E–H). Based on concordance in the pattern of dark spots on the head of *Boa imperator* (Fig. 3D), the same individual apparently was photographed in approximately the same trailside location in 2016 and 2017; this same technique for recognizing individual boas was employed in a previous survey of offshore Belizean cayes conducted in the early 2000s (Boback, 2005). We also managed to photograph a single *L. m. hoeversi* exhibiting the rarer, axanthic color morph (Fig. 3H) that appears bluish green (Platt *et al.*, 1999; Stafford and Meyer, 2000; Meerman, 2006). At least one other axanthic individual was photographed on Calabash Caye prior to 2000 (Stafford and Meyer, 2000). Two lizards, one snake, and one amphibian that we observed have not been reported previously from Calabash Caye or any of the islands of Turneffe Atoll. These are described in greater detail below.

Cozumel Whiptail (*Aspidoscelis cozumela*). We photographed four adult Cozumel Whiptails, two in 2012 and one each in 2013 and 2019 (Fig. 4). In three instances, the lizards were in leaf litter adjacent to the beach (e.g., Fig. 4A,C) and, in one case, a lizard was along the margin of littoral forest (Fig. 4E–F). *Aspidoscelis cozumela* is a parthenogenetic species, commonly described as being endemic to Isla Cozumel, Mexico (Taylor and Cooley, 1995; Taylor *et al.*, 2014). It has never been reported from any of the Belizean cayes. The individuals we photographed in 2012 and 2013 (Fig. 4A,C) exhibit a yellowish-green cast, whereas the individual we photographed in 2019 exhibited a yellow-



Figure 4. Cozumel Whiptail, *Aspidoscelis cozumela*, photographed in 2013 (A), 2012 (C), and 2019 (E,F). In two instances (A, C), individuals were crawling in leaf litter adjacent to the beach and, in one case (E), the lizard was observed along the margin of caye/cocal forest (B). A tracing of the dorsal head scales of the individual shown in (C) illustrates the arrangement of frontal [F], supraocular [SO], frontoparietal [FP], and parietal scales [P]. (D) Enlargement of the dorsal surface between the axilla and groin permits an approximate count of the dorsal granules. (F) Dorsal view of the head of the individual pictured in (E). Photos by John R. Finnerty (A, C, D) and Russell Laman (E, F).

ish-orange cast (Fig. 4E,F). Along with *A. maslini* and *A. rodecki*, *A. cozumela* is a parthenogenetic species descended from hybridization of *A. angusticeps* and *A. deppii*. The three members of the *A. cozumela* species complex can be distinguished by the number of pale longitudinal dorsal stripes (Taylor *et al.*, 2014). The adult *A. rodecki* lacks stripes, whereas *A. maslini* has eight and *A. cozumela* has six. Each of the individuals we photographed on Calabash has six stripes. The numbers of frontoparietals and dorsal granules visible in the photographs of the 2013 individual (Fig. 4B–C) are also consistent with *A. cozumela*.

Common House Gecko (*Hemidactylus frenatus*). Common House Geckos are routinely observed on Calabash Caye, chirping after dark on the inside and outside of edifices (Fig. 5A). *Hemidactylus frenatus* is a successful invasive species in tropical and subtropical habitats across the Old World that, in the last twenty years, has been reported in all of the mainland districts of Belize except the Toledo District (Stafford and Meyer, 2000; Rainwater and Platt, 2001). This represents the first report of *H. frenatus* from Turneffe Atoll or any of the offshore cayes.

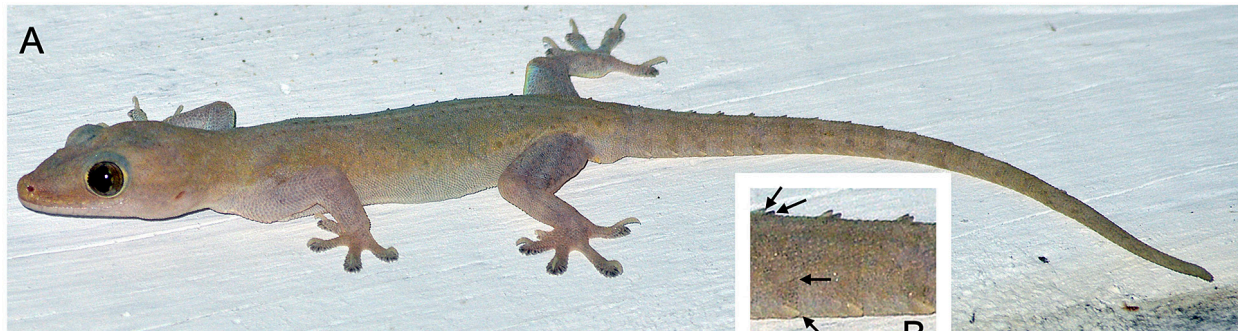


Figure 5. Common House Gecko, *Hemidactylus frenatus*, photographed in 2018 (A). (B) An enlargement of the dorsal surface of the base of the tail of the individual shown in (A). Arrows indicate four of six enlarged pointed scales belonging to the same caudal whorl. Photos by John R. Finnerty.

Schmidt's Black-striped Snake (*Coniophanes schmidtii*). Each year from 2012 to 2018, we made fleeting observations of Faded Black-striped Snakes or Schmidt's Black-striped Snakes, almost exclusively at the sunny openings to the trail that passes through littoral forest along the southeastern shore of Calabash Caye. Individuals typically were sunning themselves atop dry leaf litter at the edge of the trail or climbing among the branches of woody shrubs. We did not manage to photograph any in the field, as they typically flee rapidly when approached. In 2013, a CCFs staff member collected, photographed, and subsequently released a single individual (Fig. 6). *Coniophanes schmidtii* has been reported from numerous sites on the Yucatán Peninsula, Guatemala, and Belize (McCoy, 1969), but had not been reported from Turneffe Atoll or any of the Caribbean islands. The individual we photographed had a broad black dorsal stripe and 25 rows of dorsal scales in the anterior portion of the midbody, traits shared with other members of the *Coniophanes piceivittis* species group, which includes *C. piceivittis*, *C. schmidtii*, *C. taylori*, and *C. michoacanensis* (Bailey, 1939; Harrison, 1992; Flores-Villela and Smith, 2009; Palacios-Aguilar and Flores-Villela, 2020). Other traits consistent with the *C. piceivittis* species group include eight supralabials (Fig. 6B–C), with the fourth and fifth entering the orbit (Wilson and Meyer, 1985), and the combination of a large preocular and a small subpreocular (Palacios-Aguilar and Flores-Villela, 2020). The width of the median dorsal black stripe is five full scales plus two half-scales wide, a value that could be observed in either *C. piceivittis* or *C. schmidtii* (Flores-Villela and Smith, 2009). The thin lateral black stripes (one full-scale plus one half-scale in width) are consistent with *C. schmidtii* but not *C. piceivittis* (Bailey, 1939; Harrison, 1992; Flores-Villela and Smith, 2009).

Southern Gulf Coast Toad (*Incilius valliceps*). We observed multiple individuals of the Southern Gulf Coast Toad, *Incilius valliceps* (formerly *Bufo valliceps*) on Calabash Caye and were able to obtain photographs in 2013, 2017, 2018, and 2019 (Fig. 7). Typical of the species, all exhibited pronounced cranial crests, prominent parotoid glands approximately triangular in shape, a row of light-colored pointed warts down each side of the body from the parotoid glands to the groin, a dark lateral band immediately inferior to the row of warts, and a light-colored mid-dorsal stripe (Porter, 1970; Lee, 2000). Across its range from Mexico's Gulf Coastal Plain to Costa Rica, *I. valliceps* is

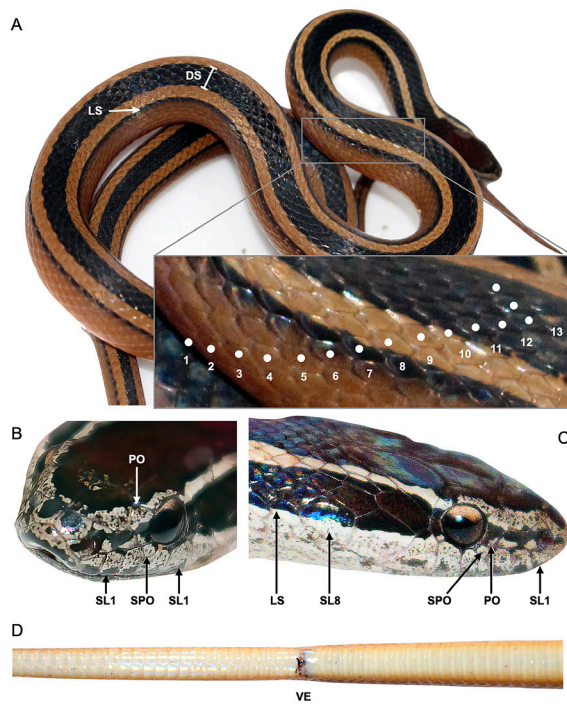


Figure 6. Schmidt's Black-striped Snake, *Coniophanes schmidtii*, captured and released on 17 November 2013. (A) Dorsal view of the body revealing the dorsal and lateral stripes. A close-up of the image (inset) permits counting of dorsal scales. (B–C) Dorsolateral views of the head. (D) Ventral view of the vent region. Abbreviations are: DS = dorsal stripe; LS = lateral stripe; PO = preocular; SL = supralabial; SPO = subpreocular. Photos by John R. Finnerty.

typically found in open or disturbed habitats (Mulcahy and Mendelson, 2000; Mendelson *et al.*, 2015). At Calabash, these toads were most commonly observed after nightfall, in short vegetation adjacent to buildings or in the leaf litter at the edge of the littoral forest (Fig. 7A,B,D). They could also be found during the day, sheltering beneath scrap lumber (Fig. 7E). The adults we observed exhibited a range of colors including tan, brown, gray, and black, and estimated snout-vent lengths (SVLs) in the range of 6–7 cm. We occasionally observed much smaller toads (~2–3 cm SVL) sharing some features with adult *I. valliceps*, including a lateral row of warts located dorsal to a darkly colored band, but lacking prominent cranial crests and parotoid glands (Fig. 7C). These small toads are thought to be newly metamorphosed individuals that had not yet developed all of the distinctive features of the adult (personal communication, J. Wiens, U. Arizona).

Half Moon Caye. During three one-day excursions to Half Moon Caye (Fig. 8A–B) conducted in 2013, 2014, and 2017, we photographed three lizard species. Half Moon Caye is a simple sand caye on the southeastern edge of Lighthouse Reef Atoll (Stoddart, 1962), located approximately 31 km ESE of Calabash Caye. All three species were photographed along the edge of broadleaf forest dominated by *Cordia sebestena* that is home to a large nesting colony of Red-footed Boobies (*Sula sula* L.). On the ground along a walking trail, we photographed large adult *Ctenosaura similis*, both female (Fig. 8C) and male (Fig. 8D). Perched on a tree branch amid the *S. sula* colony, we observed a single Cuban Blue Anole (*Anolis allisoni* Barbour 1928; Fig. 8E–F). By far the most abundant lizard we observed was *A. sagrei mayensis* (Fig. 8G–H). All three of these species have been previously reported in multiple



Figure 7. Southern Gulf Coast Toad, *Incilius valliceps*, photographed in 2017 (B), 2018 (A, D), and 2019 (E). Panels (A) and (D) are the same individual from different perspectives. This toad is most often observed in the late afternoon or evening in leaf litter adjacent to disturbed areas such as the walking trail (A, B, D). In 2019, two individuals were repeatedly observed during the day sheltering under a discarded piece of plywood in close proximity to tarantulas (E). Panel (F) is a tracing of the cranial crests and parotoid glands of the toad shown in (D). A suspected juvenile is shown in (C). Abbreviations are: CC = cranial crest; DS = dorsal stripe; LS = lateral stripe; PG = parotoid gland; PW = pointed warts. Photos by John R. Finnerty.

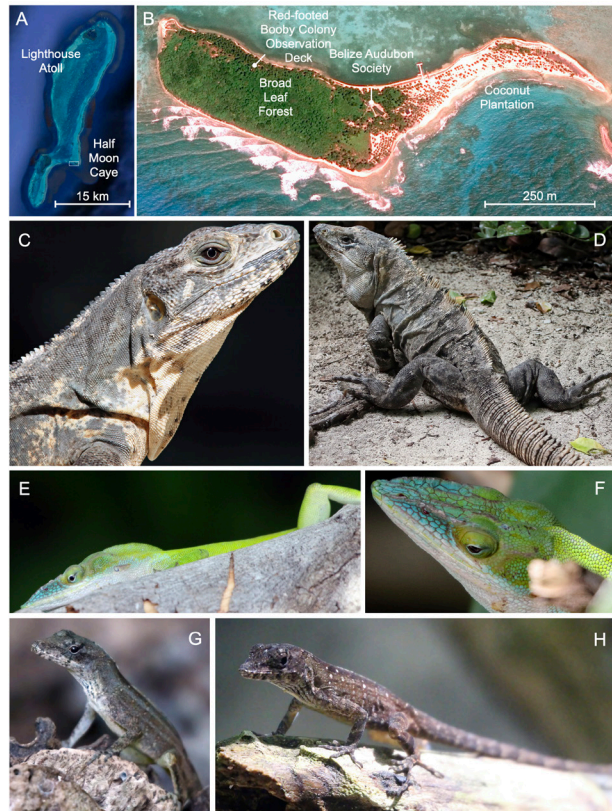


Figure 8. Lizards of Half Moon Caye. Satellite views of (A) Lighthouse Reef Atoll and (B) Half Moon Caye. (C) Adult female *Ctenosaura similis*, November 2014; (D) Adult male *Ctenosaura similis*, December 2017; (E) *Anolis allisoni*, December 2017; (F) Dorsal view of the head of the individual shown in (E); (G, H) *Anolis sagrei mayensis* photographed in November 2014 (G) and November 2013 (H). Satellite images (A, B) obtained by Landsat/Copernicus and accessed using Google Earth Pro (v. 7.3.2.5776). Images © 2021 Maxar Technologies. Photos by John R. Finnerty (C–H).

herpetological inventories from Half Moon Caye (Schmidt, 1941; Verner, 1959; Meerman, 1996; Platt *et al.*, 1999). We did not observe Green Iguanas (*Iguana iguana* Linnaeus 1758), which had been reported in prior surveys (Schmidt, 1941; Verner, 1959; Meerman, 1996; Platt *et al.*, 1999), but our photographic sampling did not extend beyond the vicinity of the waking trail along the northwestern margin of the island (Fig. 8B). Consistent with the more recent reports (Meerman, 1996; Platt *et al.*, 1999), we did not observe any juvenile *C. similis*.

Site Comparisons. To relate our observations to previous studies from islands in the western Caribbean, we clustered sites based upon the shared presence and absence of species using a principal coordinates analysis performed using the R statistical computing environment, version 4.1.0 (R Software Team, 2017). Based on the species records summarized in Table 1, we computed simple matching distances between all pairs of sites using the “dissimilarity” function (method = “matching”) in the *arules* package (version 1.6.6). We then conducted a principal coordinates analysis (PCoA) with this dissimilarity matrix using the “pcoa” function in the *ape* package (version

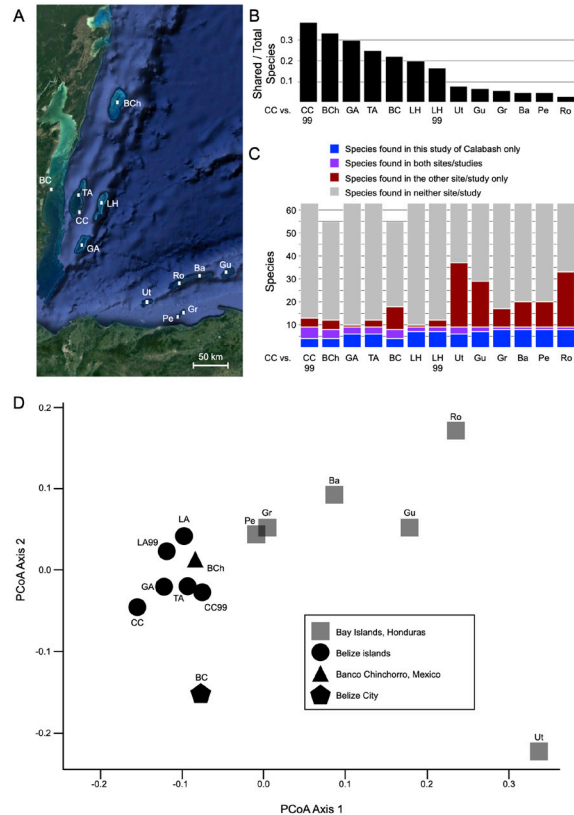


Figure 9. Comparison of the Calabash herpetofauna with that of other western Caribbean islands and Belize City. (A) Satellite view of the western Caribbean. Images obtained by Landsat/Copernicus and accessed using Google Earth Pro (v. 7.3.2.5776). Images © 2021 Maxar Technologies. (B) Fraction of taxa that are shared between this study of Calabash Caye and other sites/studies. All taxa listed in Table 1 are included in the analysis. (C) Taxa found in one site, both sites, or neither site in pairwise comparisons with the Calabash Caye species documented in this study. All taxa listed in Table 1 are included in the analysis. (D) Principal coordinates analysis of sites based on simple matching distance. All taxa listed in Table 1 are included in the analysis except for amphibians, which were not recorded in the studies of Belize City or Banco Chinchorro. Abbreviations of sites: Ba = Isla de Barbareta, HN; BC = Belize City; BCh = Banco Chinchorro, MX; CC = Calabash Caye, BZ (present study); CC99 = Calabash Caye, BZ (Platt *et al.*, 1999); GA = Glover’s Atoll, BZ; Gr = Cayo Cochino Grande, HN; Gu = Isla de Guanaja, HN; LH = Lighthouse Reef Atoll, BZ (present study); LH99 = Lighthouse Reef Atoll, BZ (Platt *et al.*, 1999); Pe = Cayo Cochino Pequeño; Ro = Isla de Roatán, HN; TA = Turneffe Atoll, BZ (other than Calabash Caye); Ut = Isla de Utila, HN.

Table 1. Comparison of herpetological species records from islands in the western Caribbean. Species photographed at Calabash Caye in this study are shaded in blue. Species not photographed at Calabash Caye in this study are shaded gray. Abbreviations: BI = Bay Islands; TA = Turneffe Atoll; Study: 1 = this study; 2 = (Henderson, 1976b); 3 =(Platt *et al.*, 1999); 4 =(Charruau *et al.*, 2015); 5 =(McCranie *et al.*, 2005).

	Locale														
	Belize City, BZ	Calabash Caye, TA, BZ	Calabash Caye, TA, BZ	Turneffe Atoll (other), BZ	Lighthouse Atoll, BZ	Lighthouse Atoll, BZ	Glovers Atoll, BZ	Banco Chinchorro, MX	Isla de Utila, BI, HN	Isla de Roatán, BI, HN	Isla de Barbareta, BI, HN	Isla de Guanaja, BI, HN	Cayo Cochino Grande, HN	Cayo Cochino Pequeño, HN	
Study	2	1	3	3	1	3	3	4	5	5	5	5	5	5	
LIZARDS															
<i>Anolis allisoni</i>					X			X		X	X	X	X	X	
<i>Anolis bicaorum</i>									X						
<i>Anolis lemurinus</i>	X												X	X	
<i>Anolis roatanensis</i>										X					
<i>Anolis sagrei mayensis</i>	X	X	X	X	X	X	X	X		X					
<i>Anolis sericeus</i>									X						
<i>Anolis utilensis</i>									X						
<i>Aristelliger georgeensis</i>								X							
<i>Aspidoscelis cozumela</i>		X													
<i>Aspidoscelis maslini</i>								X							
<i>Basiliscus vittatus</i>	X		X	X					X	X	X	X	X		
<i>Cnemidophorus lemniscatus</i>									X	X				X	
<i>Coleonyx mitratus</i>									X						
<i>Ctenosaura bakeri</i>									X						
<i>Ctenosaura melanosterna</i>													X	X	
<i>Ctenosaura oedirhina</i>									X	X					
<i>Ctenosaura similis</i>	X	X	X	X	X	X	X	X	X			X			
<i>Gymnophthalmus speciosus</i>										X	X	X			
<i>Hemidactylus frenatus</i>		X						X	X						
<i>Iguana iguana</i>	X					X	X	X	X	X	X	X		X	
<i>Mabuya brachypoda</i>	X														
<i>Mabuya unimarginata</i>			X	X					X	X		X			
<i>Phyllodactylus insularis</i>	X					X	X								
<i>Phyllodactylus palmeus</i>									X	X	X	X	X	X	
<i>Phyllodactylus tuberculosis</i>	X	X	X	X		X	X								
<i>Sphaerodactylus millepunctatus</i>									X	X	X	X			
<i>Sphaerodactylus rosaurae</i>									X	X	X	X			
<i>Scincella cherriei</i>														X	
<i>Thecadactylus rapicauda</i>									X						
SNAKES															
<i>Boa imperator</i>	X	X	X					X	X	X	X	X	X	X	
<i>Coniophanes bipunctatus</i>										X					
<i>Coniophanes imperialis</i>	X								X					X	

<i>Coniophanes schmidtii</i>	X											
<i>Drymarchon melanurus</i>					X	X			X			
<i>Imantodes cenchoa</i>					X							
<i>Leptodeira septentrionalis</i>												X
<i>Leptophis mexicanus</i>	X				X							
<i>Enulius bifoveatus</i>									X			
<i>Enulius flavitorques</i>					X							
<i>Enulius roatanensis</i>						X						
<i>Epictia goudotii</i>												
<i>Leptophis m. hoeversi</i>	X	X										
<i>Mastigodryas melanolomus</i>					X					X	X	
<i>Micrurus ruatanus</i>						X						
<i>Oxybelis aeneus</i>	X				X	X	X	X	X	X		
<i>Oxybelis fulgidus</i>	X				X							
<i>Oxybelis wilsoni</i>						X						
<i>Pseudelaphe flavirufa</i>					X	X			X			
<i>Tantilla tritaeniata</i>									X			
<i>Thamnophis proximus</i>	X											
<i>Tretanorhinus nigroluteus</i>					X	X			X			
TURTLES												
<i>Rhinoclemmys areolaria</i>											X	
AMPHIBIANS												
<i>Dendropsophus microcephalus</i>	na				na	X	X		X			
<i>Incilius vaillicept</i>	na	X			na							
<i>Leptodactylus melanonotus</i>	na				na	X	X	X	X	X		
<i>Rana berlandieri</i>	na				na	X	X					
<i>Rana vaillanti</i>	na				na				X			
<i>Rhinella marina</i>	na		X		na				X			
<i>Scinax staufferi</i>	na				na	X			X			
<i>Smilisca baudinii</i>	na				na	X	X	X	X			X

5.4.1) and plotted the first two axes using the “plot” function in the R graphics package (version 4.0.4).

We compared our photograph-based inventory of the herpetofauna of Calabash Caye to published inventories of nearby locales with similar environments (Table 1; Fig. 9A), as well as the only published inventory for Calabash Caye itself, which was compiled in the 1990s (Platt *et al.*, 1999). In addition to the islands of Turneffe, Platt and coworkers compiled species lists for Glovers and Lighthouse Atolls. Half Moon Caye on Lighthouse Atoll has been the focus of several herpetological surveys (Schmidt, 1941; Verner, 1959; Meerman, 1996; Platt *et al.*, 1999). Henderson conducted extensive observations of reptiles in Belize City between July 1970 and July 1971 (Henderson, 1973, 1974b, a, 1976b). Belize City lies approximately 33 km to the northwest of Calabash Caye. Frequent boat traffic between the two locations speaks to the possibility of anthropogenic introductions. Charruau and co-workers compiled a species list of the reptile fauna of Banco Chinchorro, an atoll whose main landmass is located approximately 42 km from the coast of Quintana Roo, Mexico, and approximately 156 km north of Calabash Caye. They used a combination of approaches, including interviews with scientists and fishermen, a review of the literature and previously collected specimens, as well as fieldwork conducted between 2011 and 2013 (Charruau *et al.*, 2015). A number of herpetological surveys were conducted in the Bay Islands (Utila, Roatán, Barbareta, Guanaja) and Cayos Cochinos, off the coast of Honduras, from the late 1960s through the early 2000s (Wilson and Hahn,

1973; Wilson and Cruz Diaz, 1993; McCranie *et al.*, 2005). The closest of these islands is approximately 160 km southeast of Calabash Caye and the islands range from approximately 30 to 70 km north of the coast of Honduras.

Overall, the species list compiled for Calabash Caye in this study exhibits the greatest overlap with the species list compiled for Calabash Caye in the 1990s, is somewhat less similar to Banco Chinchorro, Mexico, and the other Belizean islands, and bears the least resemblance to the Bay Islands of Honduras (Fig. 9B–C). A principal coordinates analysis based on simple matching distance (which considers both the shared presence and the shared absence of taxa) revealed a tight clustering of the Belizean island herpetofaunas with that of Banco Chinchorro, Mexico (Fig. 9D).

Previously reported species that were not observed. We failed to observe two lizards, one toad, and a snake that have previously been reported on Calabash Caye (Platt *et al.*, 1999). Two of these species—the Mayan Skink, *Marisora lineola* (McCranie *et al.*, 2020; formerly *Mabuya unimarginata*) and a blindsnake provisionally identified as *Indotyphlops braminus* (Daudin 1803; formerly *Ramphotyphlops braminus*)—are commonly hidden beneath the substrate and were described as rare on Calabash. For these reasons, our opportunistic photo-surveys were likely to have missed them. However, the remaining two members of the herpetofauna that we failed to observe—the Mesoamerican Cane Toad (*Rhinella horribilis* L.) and Brown Basilisk (*Basiliscus vittata* Wiegmann)—are likely to have been captured by our surveys if present on Calabash during 2012 to 2019.

The only amphibian previously reported on any of the Belizean atolls is the Cane Toad, *Rhinella marina* (formerly *Bufo marinus* L.). A single individual was reported on Calabash Caye in 1995, and another in 1997 (Platt *et al.*, 1999). A recent taxonomic revision of *Rhinella* based on molecular phylogenetic and morphometric analyses indicated a clear division between the South American Cane Toad (*R. marina*), which can be found east of the Andes, and the Mesoamerican Cane Toad (*R. horribilis* Wiegmann, 1833), which occurs west of the Andes and throughout Central America (Vallinoto *et al.*, 2010; Acevedo *et al.*, 2016; Hedges *et al.*, 2019). Presumably, any cane toads identified on the Belizean cayes would be *R. horribilis*. We did not observe *R. horribilis* over the course of our surveys from 2012 to 2019. If present in abundance, Mesoamerican Cane Toads would likely be a conspicuous component of the herpetofauna on Calabash. Like *Incilius valliceps*, *R. horribilis* tends to occupy disturbed areas near human habitation, but it is substantially larger than *I. valliceps*, e.g., SVL 80–210 versus 73–100 mm (Lee, 2000). Furthermore, whereas *R. horribilis* is broadly sympatric with *I. valliceps* on the Belizean mainland, even at the lower end of the size range for cane toads, *I. valliceps* can be distinguished from *R. horribilis* by the relatively smaller size of the parotoid glands, the row of pointy warts running down each side of the body, the dark lateral stripe, and distinct differences in the arrangement of cranial crests (Porter, 1970; Zug and Zug, 1979; Meyer and Foster, 1996; Lee, 2000; Somma, 2019).

The other conspicuous species previously reported from Calabash Caye is the Brown Basilisk (*Basiliscus vittatus* Wiegmann, 1828), which was described as common in beach scrub and littoral forest habitats on Calabash Caye and Blackbird Caye, the neighboring island to the north (Platt *et al.*, 1999). The report of Brown Basilisks on Calabash and Blackbird represents the only report of this species from Turneffe Atoll. Given its size (males can exceed 60 cm from the tip of the snout to the tail) and distinctive appearance, including a prominent tri-partite dorsal crest and bright white lateral stripes on the head, the failure to observe this diurnally active lizard over eight consecutive years (2012–2019) suggests that it has become greatly diminished in abundance since the previous report in 1999, if not absent from Calabash Caye altogether.

Conservation implications. Given its habitat diversity and history of human utilization, Calabash Caye provides a critical window into the herpetological diversity of Turneffe Atoll. The elevated beach ridge along the eastern edge of Turneffe Atoll enables the formation of strand plain plant communities and littoral forest, which are critical habitats for the herpetofauna described here. However, these same habitats are attractive sites for human development. Turneffe has a long history of human occupation, as evidenced by Mayan shell-middens found in the vicinity of Calabash Caye (Romney *et al.*, 1959). More recently, Turneffe has been a focus of intensive agricultural activity. In the early 1900s, many of the eastern cayes of Turneffe Atoll were heavily populated by domesticated animals,

primarily chickens, dogs, and pigs. Calabash housed the largest “piggery” (Stoddart, 1963) and until 1961 was home to a warehouse and collection center serving the coconut industry (Platt *et al.*, 1999). Accompanying the people and their domesticated animals, rats became a major pest. This history of heavy human utilization profoundly altered the habitats and introduced many non-native plant and animal species, both of which would have impacted the native herpetofauna.

Among the herpetofauna we documented, only the Common House Gecko is clearly not native to Turneffe. Introduced from Asia and the Indo-Pacific (Farr, 2011), *H. frenatus* quickly spread through Central America, with the first recorded sighting in Belize in the 1990s (Meerman and Garel, 2002). Its aggressive and territorial behavior, coupled with its ability to successfully inhabit heavily developed areas allowed this species to competitively displace native, endemic gecko species, such as the Tuberculate Leaf-toed Gecko (Cole *et al.*, 2005; Farr, 2011). Little research has been conducted on the interactions of *H. frenatus* with native geckos in Central America, including Belize, although Powell (2003) noted observations of *H. frenatus* displacing the Honduran Leaf-toed Gecko (*Phyllodactylus palmeus* Dixon 1968) on the island of Utila.

The greatest threat to the terrestrial biodiversity of Calabash and other islands of eastern Turneffe is habitat loss, particularly the loss of littoral forest (Platt *et al.*, 1999). Until the early 1960s, coconut plantations blanketed the elevated beach ridges along the eastern edge of Turneffe Atoll, including the entire sandy eastern third of Calabash (see Stoddart, 1962, Fig. 14). As littoral forest is restricted to these sandy elevations, coconut palms effectively displace the native habitat and the fauna that depends on it. However, the coconut industry on Turneffe was decimated in 1962 by Hurricane Hattie, which destroyed much of the infrastructure that supported it, including the warehouse and collection center at Calabash (Stoddart, 1963). With the sharp reduction of coconut palms in the northern portion of Calabash Caye, the littoral forest has recovered to some degree, and the principal present-day occupants of the island—the Belize Coast Guard, Calabash Caye Field Station, and Turneffe Atoll Sustainability Association—undoubtedly have a protective effect on the island’s biodiversity by discouraging illegal exploitation. However, only a small fraction of the original extent of littoral forest likely remains. Further decline will not only contribute directly to losses in local species abundance and/or richness by destruction of habitat, but also indirectly by exacerbating inter- and intra-specific competition among species. Consequently, protection of the remaining littoral forest on Calabash and on the other cayes comprising the Atoll is critical to maintaining herpetofaunal biodiversity. Such action is concordant with Belize’s target of protecting 10% of coastal and marine areas that include littoral forests and beach vegetation (Turneffe Atoll Sustainability Association, 2020). Of note, when the prior species inventory of the atoll was published (Platt *et al.*, 1999), Turneffe was not protected, but in November 2012, the Turneffe Atoll Marine Reserve was formed. The protection of littoral forest was nested under conservation targets for “terrestrial ecosystems” (Turneffe Atoll Management Plan 2012–2017).

Given the scarcity of particular habitats and the small size of many offshore cayes (including Calabash), the effective population sizes of island reptiles and amphibians will tend to be much smaller than mainland populations, and this alone generates conservation concerns. As Boback (2005) pointed out, island boas off the coast of Belize can be classified as Endangered according to IUCN criteria based on their small population sizes alone. Given this, non-destructive photo-surveys such as the current study could prove critical to monitoring herpetofaunal biodiversity. Such studies, even when conducted by non-experts, can be effective at monitoring common and conspicuous species.

Conclusions

The current study documents a snake, two lizards, and a toad on Calabash Caye that have not previously been reported from Turneffe Atoll: Schmidt’s Striped Snake, *Coniophanes schmidti*; Common House Gecko, *Hemidactylus frenatus*; Cozumel Whiptail, *Aspidoscelis cozumela*; and Southern Gulf Coast Toad, *Incilius valliceps*. In each instance, we were able to identify diagnostic anatomical features from photographs. Except for Common House Gecko, each of these species was photographed in multiple years.

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